Stop C

Glen Haven

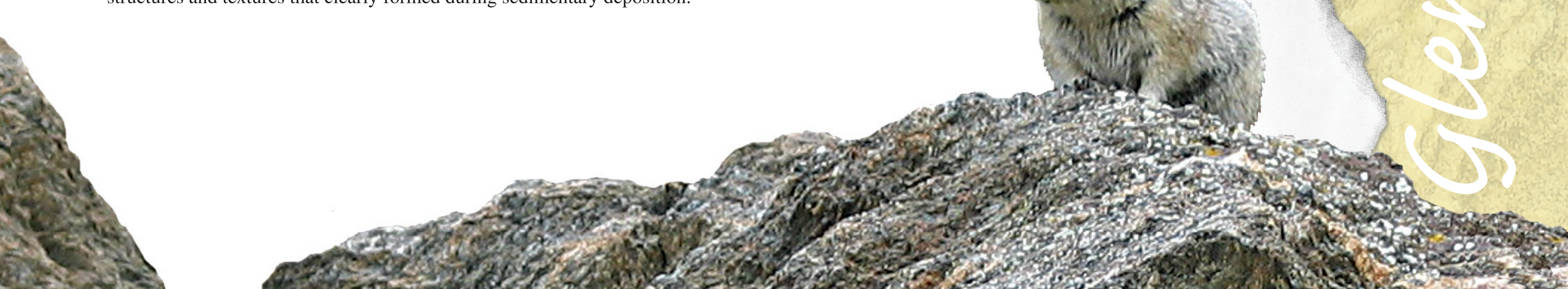
(Basement Metamorphic Rocks of the Front Range)

Directions: *Continue north on Devils Gulch Road 4.0 miles (passing the turn-off to McGraw Ranch) to the north end of the Estes Park valley. The road drops steeply to the north through several switchbacks leading 2.4 miles down to the town of Glen Haven and the valley of the North Fork of the Big Thompson River. From Glen Haven, continue eastward about 0.6 mile to a sweeping left turn in the road. Stop at the large graveled parking area along the right side of the road beneath towering outcrops of banded black and gray rock.*

Fine-scale layering shown by light and dark bands probably originated as sedimentary layering in an ancient ocean basin. *Photograph by Bill Braddock.*

Stop at this roadside outcrop to examine features of the oldest rocks in this part of the Rocky Mountains. These gray, brown, and black banded rocks are classified as metamorphic rocks (*meta* = change; *morph* = form or shape) because they have been changed by extreme heat and pressure. Take a few minutes to look closely at the outcrops.

These rocks are mixtures of granular, light-colored mineral grains (mostly quartz and feldspar) and flaky, dark-colored mineral grains (mostly biotite and hornblende). The mineral grains are arranged in banded layers that are generally parallel to each other. The layers differ in the proportions of light- and dark-colored minerals, grain sizes, or color. Patterns of layers resemble those of silt and sand deposited by running water (sedimentary deposits). Geologists think the layering in these metamorphic rocks probably started out as sedimentary layering because the chemical compositions of these rocks are similar to compositions of sediments deposited in modern streams and oceans. More conclusively, similar rocks exposed about 15 miles east of here, which were not changed so strongly by metamorphism, show structures and textures that clearly formed during sedimentary deposition.



Glen Haven

11 Stop C—Glen Haven

Some of the layering has a distinct appearance that geologists know formed by partial melting during intense metamorphism. These distinct layers have a granular, light-colored center of quartz and feldspar bordered by thin margins of biotite and other dark minerals. The minerals that melt at lower temperature (quartz and feldspar) formed the center of the layer, but the dark minerals that only partly melt at higher temperature were displaced outward, forming a concentrated residue along both sides.

The rocks show fluid-looking, wavy convolutions in the layering. The distance between the ridges and furrows of these folds ranges from less than an inch to several feet. If you step back about 10 paces and survey the whole outcrop, you'll see larger folds (tens of feet between the ridges and furrows). Note that most folds "lean to the right" from this vantage point.

Geologists infer from this kind of evidence that most of the folding occurred in a single, long-lasting event. The general shape of the folds indicates that the layering was pushed together and crumpled like a throw rug on a smooth floor. Different parts of the layered package were able to slide past each other at different rates and so they folded a bit differently. Thinly layered parts tend to show small, tight folds, and thicker layers fold with longer wavelengths. You can see the same range of fold sizes in a crashed car: thin body panels crumple, fenders bend and twist, and strong parts of the frame only bend a little.

▲ **(Above)** ***Distinctive layering is shown by light-colored seams bordered by thin bands of concentrated dark minerals. Geologists infer that this rock was partially melted, causing the melted (light) minerals and the unmelted (dark) minerals to segregate, at the same time it was folded.***

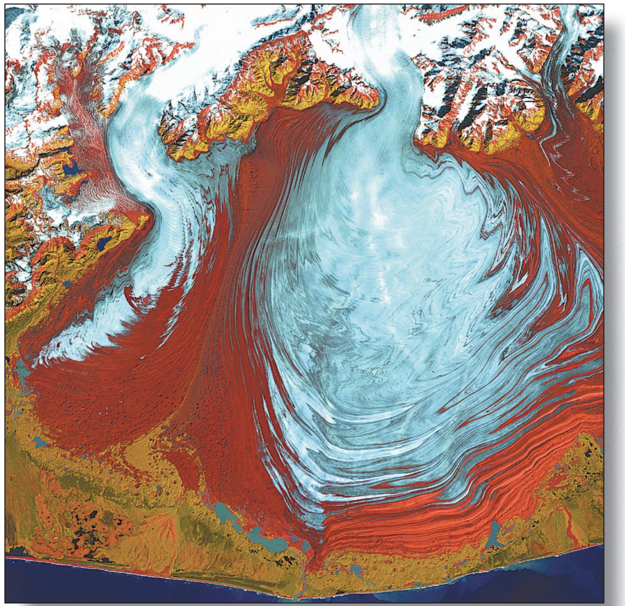
◀ **(Left)** ***Wavy patterns of deformed layering show that these rocks folded, crumpled, and sheared under extremely high temperatures and pressures.***

How Do Rocks Fold?

These contorted layers record deformation that must have taken place very slowly over very, very long periods of time. The intense heat and pressure that led to partial melting allowed these rocks to soften and deform, and the entire folding event probably required many millions of years to complete.

The slow process of rock deformation can be compared to the relatively fast deformation observed in a flowing glacier. Glacier ice seems to be hard and inflexible, but, over time scales of years and decades, we can observe glaciers deform and flow.

The shape and size of a fold partly depends on the thickness of the folded layer. Thicker layers generally form broader folds.



Hard glacial ice of the Malaspina glacier in Wrangell-St. Elias National Park, Alaska, flows slowly downward and outward, creating elaborate folds in the stripes of transported moraine. *NASA-USGS Landsat 7 image, false-color, August 31, 2000.*

How Old Are These Rocks?

The metamorphic rocks that make up the core of the Front Range are the oldest rocks known in the region. Geologists use various laboratory techniques to learn the "absolute" numerical ages of these rocks. These techniques are based on the known rates at which naturally occurring radioactive elements decay. For example, minerals and rocks that contain potassium, rubidium, uranium, or thorium can be analyzed to determine how much of the radioactive element remains in comparison to the amount of radioactive decay product. Analysis of these metamorphic rocks indicates they stopped melting, solidified, and started their radioactive "clocks" about 1.75 billion years ago (that's about 30 percent as old as the age of the Earth).